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Detection threshold of visual displacement in a networked flight simulator

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Abstract

Networked flight simulators facilitate team training by creating exercise environments and simulations representative of real-world operations. However, networked simulators are often plagued by connectivity issues, such as constant and variable network delay. Network delay can cause positional discrepancies or visual jitter in the flight path of a moving model which could effect pilots overall perception of fidelity of motion. To reduce the visibility effects of network delay, image generator algorithms, such as model position smoothing, can be enabled. The use of smoothing however, can also contribute to error in the motion path of an entity. This research aims to determine the detection threshold of visual displacement for a typical flight task, formation flight, as a function of simulated distance (100, 200, & 400 meters) and smoothing (no smoothing or smoothing across 1 second). The results show a significant increase in detection threshold with increases in distance. The addition of model position smoothing also increased the amount of visual displacement required for detection. The implications of these results, as well as plans for future research on network transport delay will also be discussed in this paper.

Introduction

To provide a realistic team-training environment, simulators are networked enabling trainees to perform exercises emulating real-world conditions. When simulators are networked, especially over large geographical areas, interactions between them become more complicated. According to Toet (1995) three important issues related to the realism of time must be considered when networking simulators. These issues concern the timing consistency of the virtual world, delays, and the overall representation of time in a simulator.

The level of realism of an entity in a networked simulator depends upon factors such as network delay, thresholds used to determine when a simulated position error

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14. ABSTRACT
Networked flight simulators facilitate team training by creating exercise environments and simulations representative of real-world operations. However, networked simulators are often plagued by connectivity issues, such as constant and variable network delay. Network delay can cause positional discrepancies or visual jitter in the flight path of a moving model which could effect pilots overall perception of fidelity of motion. To reduce the visibility effects of network delay, image generator algorithms, such as model position smoothing, can be enabled. The use of smoothing however, can also contribute to error in the motion path of an entity. This research aims to determine the detection threshold of visual displacement for a typical flight task, formation flight, as a function of simulated distance (100, 200, & 400 meters) and smoothing (no smoothing or smoothing across 1 second). The results show a significant increase in detection threshold with increases in distance. The addition of model position smoothing also increased the amount of visual displacement required for detection. The implications of these results, as well as plans for future research on network transport delay are also discussed in this paper.

15. SUBJECT TERMS
Networked flight simulators; Team training; Exercise environments; Connectivity; Network delay; Visual jitter; Moving models; Perception; Motion fidelity; Visibility; Flight tasks; Smoothing; Visual displacement; Detection threshold;

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should be corrected, and algorithms used to correct position errors. These factors can interact and produce positional discrepancies between the position provided by a local model of an entity, which is used to render the entity, and the actual position of the entity. The correction of positional discrepancies via the use of smoothing within the Image Generator (IG) results in a positional displacement of the rendered entity (Lin, Wang, Wang, and Schab, 1995). The purpose of this experiment was to assess the detection threshold of positional error or displacement threshold as a function of distance from eyepoint, and positional smoothing performed by the IG. This data will contribute to a larger research paradigm to assess the impact of network parameters on task performance in a flight simulation environment.

Methods

Five observers were used to assess the effects of distance from eyepoint and position smoothing on the detection threshold of positional displacements, or jitter caused by network transport delay. The design of this experiment included two levels of position smoothing (no smoothing and 1 sec of smoothing), three simulated distances (100, 200, and 400 meters) and thirteen displacement amplitudes (between 0 and 8.192 meters) for each distance. We used a repeated measures design for a total of 2 (smoothing) × 3 (distances) × 13 (displacement amplitudes) × 5 (observers) ×15 (repetitions).

Stimuli consisted of a blue sky and a fully textured, realistic three-dimensional model of an F-16. Visual scenes were rendered with MetaVR's real time visualization application, Virtual Reality Scene Generator (VRSG) ™. Custom software, written in C++, was used to control the characteristics, timing, and sequencing of the motion sequences, to communicate with VRSG, and to record the observer's responses.

A trial consisted of one, 2-second presentation of the F-16 on a stationary visual scene. The blue-sky background was present continuously throughout each block of trials. Simulated distances were varied across blocks of trials. For each block of distance trials there were a range of 13 different displacement amplitudes. Following each presentation of the aircraft text was presented on the screen to ask observers "Did you detect jitter?" and to cue responses of "Yes" or "No."

Results

The results were analyzed by fitting a Weibull curve to the mean response data from each observer for each combination of smoothing and distance to obtain a threshold at the 63% level of performance. The data was then converted to visual angle in arcmin to assess whether observers required different visual information for each combination of conditions. Both the raw distance and the visual angle data were then subjected to a repeated measures analysis of variance (ANOVA) to assess the presence of any main effects or interactions between distance and position smoothing. Finally, t-tests were computed to determine if there was a difference in detection threshold between the no smoothing and position smoothing conditions for both the raw distance and visual angle data.

Figure 1 shows detection thresholds in meters for the two smoothing conditions across the three distance conditions. The figure shows that for both smoothing conditions, detection threshold generally increased as a function of distance. The figure also shows that the addition of smoothing also increased detection thresholds. An ANOVA revealed that the effect of simulated distance was statistically significant $F(2, 8) = 6.97$, $p < 0.05$. A post-hoc pairwise comparison showed that the following simulated distances were significantly different ($p < 0.05$): 100 m versus 200 m and 100 m versus 400 m.

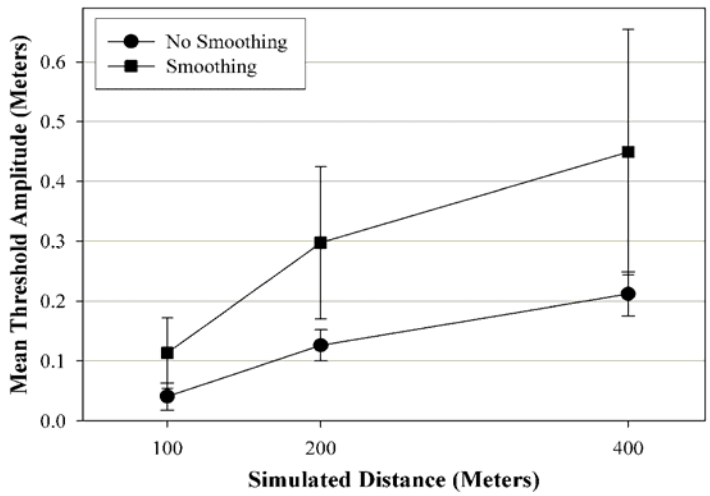

Figure 1. Mean threshold amplitudes in meters for three simulated distances and two smoothing conditions. The circle represents the no smoothing enabled condition and the square represents the 1 s smoothing condition. Error bars represent the actual computed standard error of the mean.

We did not find a significant overall effect of smoothing, or an interaction with distance from eyepoint. Figure 2 shows the proportion of correct responses out of fifteen trials for the two smoothing conditions averaged across all subjects and simulated distances. Since there is a visual difference in overall detection threshold between the two smoothing conditions, we also wanted to test the null hypothesis that there would not be a difference between the no smoothing and 1 s smoothing thresholds using an a priori contrast. We found, using a two tailed t-test, a significant difference in detection threshold between the no smoothing and smoothing conditions, $t(13) = -2.26$, $p < 0.04$.

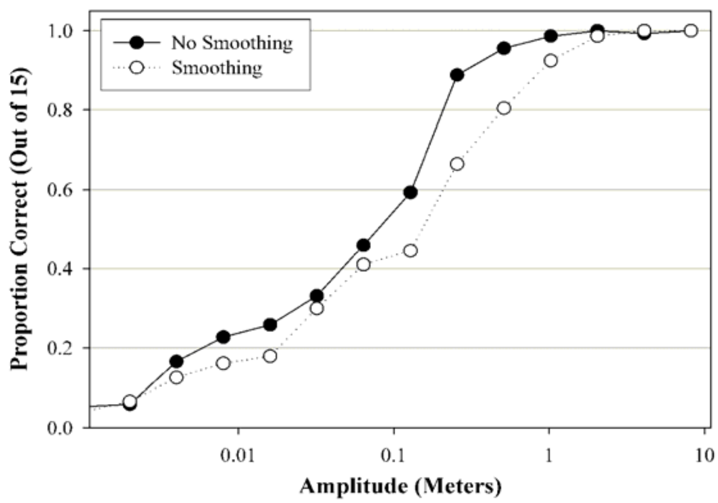

Figure 2. Percentage of correct responses out of fifteen trials for the two smoothing conditions averaged across all subjects and simulated distances (each point represents 225 data points). The black circle represents the no smoothing condition and the white circle represents the 1 s smoothing condition.

To assess the effect of distance and position smoothing on the visual angle of the detection threshold, we ran a Repeated Measures ANOVA. There were no significant effects or interactions for either distance or smoothing. Figure 3 shows the detection thresholds in arcmin for the two smoothing conditions across the three distance conditions. The figure shows that an increase in visual angle of the displacement amplitude was not required for detection as the simulated distance was increased. However, it is shown that the addition of smoothing did increase the visual angle of the detection threshold. We found, using a two tailed t-test, a significant difference in the visual angle of the detection threshold between the no smoothing and smoothing conditions, $t\ (13) = 2.16$, $p < 0.01$.

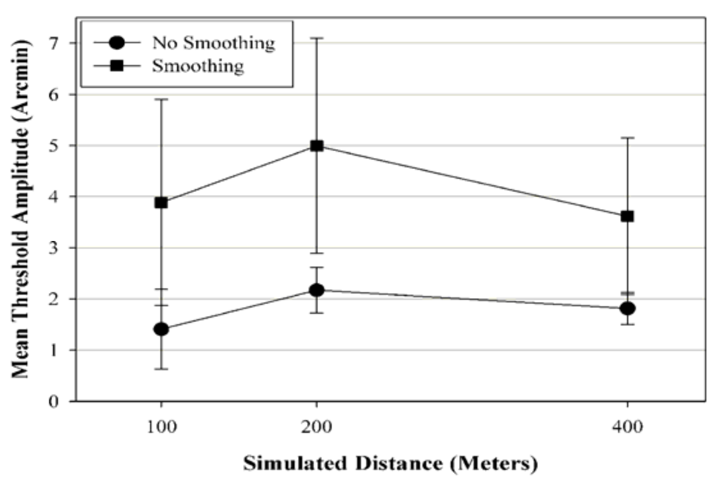

Figure 3. Mean threshold amplitudes in arcmin for three simulated distances and two smoothing conditions. Circles represent no smoothing enabled condition and squares represent the 1 s smoothing condition. Error bars represent the actual standard error of the mean.

Discussion

The results of this experiment show that increasing simulated distance increases the amount of displacement, in simulation space, required to detect target aircraft motion. However, when the displacement was expressed in units of visual angle, the effect of simulated distance was not significant, indicating that the thresholds were determined by angular displacement. Additionally, under the conditions used in this study, smoothing approximately doubled angular displacement thresholds.

Under all conditions, displacement thresholds were small - approximately 2 arcmin for the unsmoothed condition and 4 arcmin for the smoothed condition. This translates into displacement thresholds of ½ pixel and 1 pixel for the unsmoothed and smoothed conditions, respectively. In fact, studies performed under optimal conditions report displacement thresholds of 2 arcsec (Boff, Kaufman, & Thomas, 1988).

The finding that smoothing, which decreases target velocity, increased the displacement threshold is not surprising. Smoothing is used in a networked environment to reduce the visual saliency of the displacement and provide a more realistic looking flight path to an observer. However, the smoothed flight path will provide a less accurate representation of the true flight path (Lin, et al, 1995). The high sensitivity of the visual system in detecting displacement shown in this study and others suggests that the positional error of the smoothed flight path can be encoded by the visual system and could, therefore result in performance degradation. Furthermore, because the smoothed flight path looks realistic it may alter a pilot's performance whereas the unrealistic jump with smoothing disabled can be easily discounted by the pilot. Therefore the benefits and advantages of smoothing are still subject to debate and to future research.

As stated previously, this experiment is the first in a series of experiments designed to determine the effect of network conditions on flight tasks in a networked simulator training environment. At the Air Force Research Laboratory in Mesa, AZ we are conducting a detailed evaluation of the actual physical positional discrepancies that occur as a function of the overall load of the network. This evaluation will allow us to compare our results from the present experiment to actual positional discrepancies that would manifest as a result of network load. We are also conducting another evaluation to assess the different types of positional discrepancies induced by network packet load over a long-distance network (i.e. from Mesa, AZ to Melbourne, Australia).

References

Boff, K.R., Kaufman, L., Thomas, J.P. (Eds.), *Handbook of Perception and Human Performance*, *section* 1.602, John Wiley & Sons, NY, 1988, 198-200.

Lin, K., Wang, M., Wang, J., & Schab, D. (1995). The smoothing of dead reckoning image in distributed interactive simulation. *Proceedings of the 1995 American Institute of Aeronautics and Astronautics Flight Simulation Technologies Conference*, 83-87.

MetaVR, Inc. (2007). MetaVR Virtual Reality Scene Generator™ (VRSG™) Version 5.2 Users Guide, Brookline, MA.

Toet, A. (1995). *Perceptual Issues of DIS Quality* (Report TNO-TM 1995 A-43). Soesterberg, NL: TNO Human Factors Research Institute.

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